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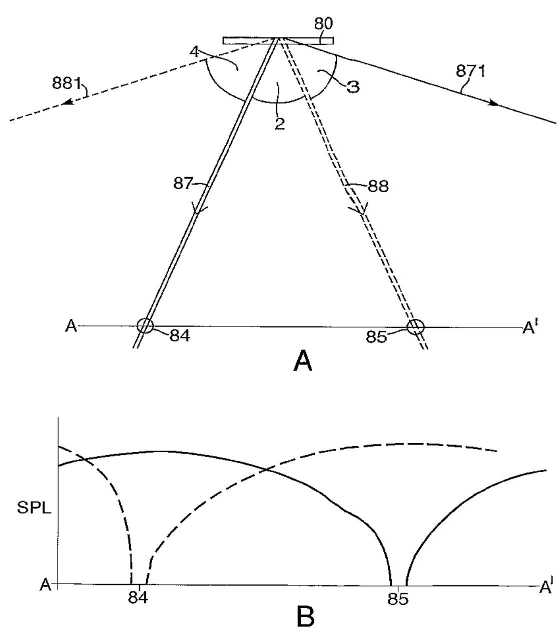
(54) Title: METHOD OF CREATING A SOUND FIELD



(57) Abstract: A method of creating a sound field which allows two users in the same room to listen to different programmes. A sound beam representing a first sound signal is beamed to a first listener and a sound beam representing the inverse of that signal is beamed to a location the other side of the second listener. The symmetry of the sound b earns about the second listener causes the sound field to be very quiet at the second listener's position. Thus, the first; listener can listen to an audio programme while the second listener hears nothing even though be may only be a metre or so away from the first listener. Linear superposition means that a different audio programme can be beamed to the second listener and a quiet spot in respect of this different audio programme can be provided at the position of the first listener. This allows two people in the same room to listen to different audio programmes, with no, or very little, interference between the programmes, even at low frequencies.

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METHOD OF CREATING A SOUND FIELD

FIELD OF THE INVENTION

This invention relates to methods and apparatus for creating a sound field, particularly a sound field for home entertainment or professional sound reproduction applications. Even more particularly, it relates to a device including an array of electro-acoustic transducers capable of generating beams of audible sound and methods of cancelling sound beams in selected directions.

BACKGROUND OF THE INVENTION

The commonly owned published International Patent application numbers WO01/23104 and WO 02/078388 describe sonic steerable or phased array antennae and their use to achieve a variety of effects. The applications describe a method and apparatus for taking an input signal, replicating it a number of times and modifying each of the replicas before routing them to respective output transducers such that a desired sound field is created. This sound field may comprise a directed beam, focussed beam or a simulated origin. The direction of a beam is controlled by delaying the signal fed to each transducer across the array, leading to constructive interference at a predetermined location of all or some of the signals emitted from the transducers of the array. Further, several input signals or channels may be reproduced simultaneously, producing multiple beams directed in different directions. Thus a stereo effect is produced from two beams directed to right and left, while surround sound is achieved by directing five sound beams to centre, left, right and rear-left and rear-right, the beams being reflected from walls and ceilings as required to reach the listener from the appropriate directions. The apparatus of the type described in these applications is known as a Sound Projector.

A further effect first described in the above-mentioned WO01/23104 and further elaborated in the commonly-owned International Patent application WO2004/075601 is the reproduction of two entirely separate audio programmes in two different directions, such that two listeners can listen to separate audio programmes, an application referred to as 'dual mono'. However, with the described known methods, some interference from one sound beam to the other can occur, such that each listener hears some sound from the other listener's sound beam. This is particularly the case at

low to mid audio frequencies where the sound beam has significant width.

It would therefore be desirable to reduce this sound interference to improve the dual mono effect. Further, when a single sound programme is directed to a first person, a second person in the same listening space (room) may also hear the sound. It would further be desirable to provide a quiet location within the room where the sound is inaudible (or at least very weak).

WO01/23104 discloses, with reference to Figures 17 to 19 of that document, the use of a "null signal" which is directed to a point in the sound field where it is desired to provide a quiet location. The "null signal" comprises an inverse of the signal that is calculated to already exist at the desired quiet location. This method has the drawback that it is necessary to measure or calculate the signal already existing at the quiet location. This can in practice be very difficult because it is necessary to either provide a microphone at the desired location or to employ a powerful processor to make the necessary calculations.

The actual sound that exists at any point in the sound field results from a combination of sound signals from each of the transducers of the sound projector. When the sound projector is directing a sound beam to a different location, the sound at the desired quiet location is a complicated superposition of signals which can linearly add up at some frequencies and cancel each other out at other frequencies. Thus, even if the processing power were available to reasonably accurately determine the sound signal existing at the desired quiet location, it would be difficult to ensure that a correctly inverted version of the signal is beamed to the desired quiet location with the correct phase and amplitude characteristics across all frequencies.

It would be desirable to implement a simpler method of providing a quiet location that does not require the simulation of the sound field in a processor so as to determine a complicated nulling signal.

SUMMARY OF THE INVENTION

The present invention stems from the realisation that symmetry in the sound field can

be exploited to simplify the calculations required and yet still provide accurate and directed nulling at a point in the room.

In a first aspect, the method provides a method of creating a sound field comprising a strong first sound signal at a first location and a weak or null first sound signal at a second location, said method comprising: directing a first sound beam towards the first location to create said strong first sound signal there; directing a second sound beam towards a third location different to said second location, such that the first and second sound beams cancel at said second location to create said weak or null first sound signal there.

Preferably the second location lies between the first and third location and, more preferably still, a line from the sound projector to the second location bisects the angle between a line from the sound projector to the first location and a line from the sound projector to the third location.

The invention thus takes advantage of the discovery that if a first sound beam is directed in a first direction and an inverse of this sound beam is directed in a different direction, a point lying between the two sound beams and equidistant from the two sound beams will receive signals having the same amplitude but opposite phase which tend to cancel each other out. The invention therefore provides that it is merely sufficient to direct an inverse of the sound beam to be nulled in a direction that is the other side of the quiet location from the sound beam to be nulled. It can then be deduced that the quiet location is silent, or at least very quiet, due to symmetry of the sound beam with its inverse about a line linking the quiet location to the sound projector. The invention therefore utilises the counter-intuitive realisation that no sound signals need to be beamed directly to the nulling point itself.

When the transducers are located in a straight line, or in a flat planar array, as is often preferable, the width of the sound beams produced at any frequency can vary with the angle of such sound beams from the line or plane of the array. In general, sound beams that are directed more laterally (that is to say with a component that is more parallel to the line or plane of the array) tend to be wider than sound beams that are directed perpendicularly out of the array at any given frequency. To account for this,

two corrections can be applied to the second sound beam. The second sound beam can be reduced in amplitude to ensure that, at the quiet position, the magnitude of the second sound beam matches the magnitude of the first sound beam and proper cancellation occurs. Alternatively or additionally, the second sound beam can be directed at an even greater angle from the perpendicular to ensure that it falls off sufficiently at the quiet location so as to match the magnitude of the first sound beam at that location.

In order to provide a dual-mono effect, third and fourth sound beams can be superimposed on the sound field such that a third sound beam representing a second sound signal is directed at the point where said first sound signal is quiet and a fourth sound beam is directed so as to create a quiet location (for the second sound signal) at the point where said first sound signal is strong. In this way, a listener at the first location hears substantially only the first sound signal and a listener at the second location hears substantially only the second sound signal.

As the beam width of sound signals reduces with increasing frequency, the provision of a quiet spot with respect to a sound signal can be limited to the lower frequencies where the beam width is wider and where more interference is expected. As such, the second and/or fourth sound beams can be limited to comprise frequency components under 2 kHz. Other cut off points, such as 1.5 kHz or 1.2 kHz can instead be used.

The sound beams can be provided by an array of output transducers that are disposed in a horizontal line. In this case, the sound beams can be directed horizontally. Alternatively, a two-dimensional array can be used in which case the sound beams are directable in three dimensions.

To improve the usability of the device, a remote control may be provided which allows the user to input listening positions. Such information can be used by the processor in the sound projector to calculate the angles of the necessary beams such that appropriate signals are received at the selected listening positions. Provision may be made for the user to fine-tune the beam angles using the remote control.

In a second aspect, the invention provides apparatus for creating a sound field that

comprises a strong first sound signal at a first location and a weak or null first sound signal at a second location, said apparatus comprising: a plurality of sonic output transducers capable of directing more than one sound beam, each beam being different, wherein, in use, a first sound beam is directed towards said first location to create said strong first sound signal there; a processor arranged to calculate the angle of a second sound beam based on said second location, such that said second sound beam is not directed towards said second location but instead towards a third location: wherein, in use, said second sound beam is directed towards said third location such that the first and second sound beams cancel at said second location to create said weak or null first sound signal there.

The apparatus is preferably arranged to implement the above-described method. For example, an inverter can be used to invert the first sound signal so as to provide the signal for the second sound beam. An amplitude adjuster can be used to adjust the amplitude of the second sound beam so as to account for the fact that the beam may be wider than the first sound beam. Alternatively or additionally, the processor may correct for this beam width effect by adjusting the angle of the second sound beam so as to be greater than the angle of the first sound beam measured from a line joining the quiet spot to the sound projector.

In a third aspect, the invention provides a method of creating a sound field in which a strong sound signal is heard by a first listener and a weak or null sound signal is heard by a second listener. The method provides a strong sound signal in a first location and a weak or null signal in a second location by directing a first sound beam towards the first location and directing a second sound beam in a different direction such that the first and second sound beams substantially cancel at the second location.

In a fourth aspect, the invention provides a method of creating a sound field comprising a strong signal in a first direction from a sound emitter and a weak or null signal in a second direction from said sound emitter, by:

directing a first sound beam from said emitter in said first direction;

directing a second sound beam from said emitter in a third direction;

wherein said second direction lies between said first and third directions, and said second sound beam is an inverse of said first sound beam.

The effect of the method of the invention is to provide a location (along the second direction) where any sound from the first sound beam is effectively cancelled. Thus a first listener sitting at a first location in the first direction hears full sound while a second listener sitting at a second location in the second direction hears nothing or very little.

The sound emitter may be any device capable of producing directed beams of sound, or even a collection of separate devices (loudspeakers) emitting separate signals. Preferably however, the sound emitter is a transducer array, more preferably of the type known as a Sound Projector and described in WO01/23104. Preferably the Sound Projector comprises five or more transducers. The first and third sound beams comprise sound in the audible frequency range, that is, from about 20 Hz to about 20 kHz. The abovementioned first, second, third and fourth directions are directions from a common point, preferably the centroid of sound generation, which is usually the centre point of the face of the sound emitter or Sound Projector. The second direction lies between the first and third directions. Preferably, the angle between the first/second directions is the same as or similar to the angle between the second/third directions, such that the first and second beams are effectively mirrored about the second direction. This produces good sound cancellation in the second direction. As discussed above, in the case where the first and second listener positions (and hence the first and second directions) are significantly off axis or asymmetrically positioned with respect to a perpendicular line from the face of the sound emitter, better cancellation can be achieved by adjusting the amplitude of the second or fourth sound beams or by making the angles not exactly equal. In this case, the angle between the second/third directions may be greater by a few degrees (up to 10 degrees or more) than the angle between the first/second directions.

The first sound beam carries the desired audio signal and the second sound beam carries a signal which is essentially an inverse of the first beam, that is, antiphase to the first signal at all frequencies. While the second beam is essentially an inverse, its amplitude and or phase may be designed to differ slightly (by up to a few percent, perhaps up to 20%) from the exact inverse as necessary to improve the cancellation effect. This modification is particularly applicable when the first and second

directions are significantly off-axis or asymmetrical, as above. Thus the angles, phase and amplitude of the sound beams can be modified to optimise the cancellation effect.

The effect described allows a first listener to hear a sound signal, while the other does not. In a further aspect of the invention, this effect is simultaneously replicated the other way round by emitting a further pair of sound beams, such that the second listener hears a different audio programme, which is cancelled in the first listener's direction. Thus two listeners can simultaneously hear two different audio programmes (perhaps associated with two different video or television programmes) without interference from each other's programmes. In a yet further aspect of the invention, additional sound beams provide further channels for one or more listeners or further audio programmes for additional listeners. Some or all of these sound beams may be cancelled at the locations of the other listener(s) in the manner described.

These and other aspects of the invention will be apparent from the following detailed description of non-limitative examples, making reference to the accompanying drawings, in which:-

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 illustrates the known Sound Projector producing two audio beams for two listeners (prior art);

FIG 2 shows a schematic plan view in FIG.2A and a Sound Pressure Level (SPL) plot in FIG.2B of the method of the invention for an on-axis null position;

FIG 3 shows a schematic plan view in FIG.3A and a SPL plot in FIG.3B of the method of the invention for an off-axis null position;

FIG 4 shows a schematic plan view in FIG.4A and a SPL plot in FIG.4B of the method of the invention for two listeners receiving two different audio programmes;

FIG 5 shows a simulated SPL plot for two pairs of sound beams at 400 Hz;

FIG 6 shows a simulated SPL plot for two pairs of sound beams at 1000 Hz; and

FIG 7 shows a simulated SPL plot for a pair of sound beams at 400 Hz and another pair at 1000 Hz.

DETAILED DESCRIPTION

Figure 1 is a schematic representation of a Sound Projector 80 used in dual mono mode as taught in co-owned international application WO2004/075601. The Sound Projector 80 is positioned under a television set 81, for example a flat screen LCD TV, mounted vertically (shown in perspective view in Figure 8 for clarity). The television 81 is operating in multiple window mode (also known as picture on picture mode), showing a first programme V1 on the left half 82 of the screen and a second programme V2 on the right half 83 of the screen. The programmes are being viewed by two people, 84 and 85, shown seated on a sofa 86 positioned in front of the TV 81. The audio track A1 corresponding to programme V1 is reproduced by the Sound Projector, and the resulting sound beam 87 is steered in the direction of the person 84 sitting on the left end of the sofa 86. The solid lines 870 delineate the limits of the beam 87. The width of the beam is frequency dependent, the beam being narrower at higher frequency; the beam width shown corresponds to a mid-frequency of a few kHz. Similarly, the audio track A2 corresponding to programme V2 is reproduced as a sound beam 88 directed to a second person 85 sitting at the right end of the sofa 86. The dashed lines 880 delineate the limits of the beam 88. Both beams 87,88 are shown focussed at the vicinity of the listener positions, 84,85. At the position of the sofa 86, the two sound beams do not overlap. Thus the left person 84 hears only the left audio track A1 corresponding to the left picture V1, and similarly the right person 85 hears only the right audio track A2 corresponding to the right picture V2. However, if the audio tracks A1 and A2 contain low frequency components, the beam width of these components is greater and some interference may be heard.

Figures 2 to 4 show plan views of the Sound Projector operating in accordance with several aspects of the present invention. As in Figure 1, a Sound Projector 80 emits one or more sound beams and there are two listeners, denoted by circles 84 and 85 lying on line A-A'. In Figures 2 to 4, the sound beams are represented by lines denoting the centre line of the beam, and the direction from the front centre of the Sound Projector to the second listener 85 is shown as a line 11.

In Figure 2A, the Sound Projector 80 emits a sound beam 87 (represented as a double line) in the direction of the first listener 84. At high frequencies (above a few kHz) the beam is narrow and little sound from the beam reaches a second listener 85 spaced from the first listener 84. At low frequencies however (less than 1 or 2 kHz) the beam is broader and considerable sound from the beam 87 can reach the second listener 85. According to one aspect of the invention, a second beam 871 (denoted as a single line) is directed to the other side of the second listener 85, that is, it is directed to the side opposite to the side where first listener 84 lies. The second sound beam 871 is an inverse of the first beam 87 (i.e. it is in antiphase at all frequencies) and the two beams are disposed symmetrically about the second listener 85. In this case, listener 85 is located on-axis with relation to the Sound Projector, that is, on the perpendicular from the front centre of the Sound Projector. The two beams 87 and 871 form angles 2 and 3 respectively with the direction 11. In this case, angles 2 and 3 are equal. By symmetry, the sound reaching the listener 85 from the two beams 87 and 871 is equal in magnitude and opposite in sign, and the net sound amplitude is therefore zero. This is shown graphically in Figure 2B, where the horizontal axis is the position along the line A-A' on which the listeners 84,85 sit and the vertical axis is the Sound Pressure Level (SPL). The summed amplitudes of the two beams 87 and 871 is high at the position of the listener 84 and at another position to the right of listener 85; however at the location of the second listener 85, the summed sound pressure amplitude is very small.

Figure 3 is a variant of the arrangement of Figure 2 in which neither listener 84,85 is on axis, as would normally be the case in a domestic listening arrangement. As before, the sound beam 87 is directed at first listener 84 and an inverse sound beam 871 is directed to the opposite side of second listener 85, such that the summed sound pressure amplitude at 85 is zero. Again, this is displayed graphically in Figure 3B.

The width of a sound beam is not only affected by its frequency components, but also to some extent by the angle at which it is emitted from the sound projector 80. The beam 871 in Figure 3A is emitted at a greater angle from a line perpendicular to the sound projector 80 than is the sound beam 87. As such, the sound beam 871 will be wider at any particular frequency than the sound beam 87. In a preferable aspect of the invention, this effect is corrected. Such correction can be achieved by fine-tuning

the amplitude of the cancellation beam 871, generally by making its amplitude slightly smaller than that of beam 87 and/or modifying its phase (or time delay) relative to beam 87 by a small amount, whilst directing the beam such that the angles 2,3 are approximately or exactly equal.

Alternatively or additionally, in this more general case where the second listener 85 is not on axis, the angles 2 and 3 between the beam directions 87, 871 and direction 11 (from the Sound Projector to the second listener 85) can be made unequal. Generally, angles 2 and 3 are of the same order, with angle 3 being greater than angle 2. For example, a typical domestic living room measures 3-4 m wide by 4-5 m long. Typically a television with its associated speakers is situated against one wall and seating (such as a sofa or armchairs) is situated against the opposite wall. Thus the listeners may be 2-3 m from the Sound Projector (which is co-located with the television) and may be 1-2 m apart. The angle 2 between the listeners is then typically of the order of 20-30 degrees. The angle 3 between the directions of the muting beam 871 and the null listener direction 11 is of a similar order, but generally a few (1-10) degrees larger, depending on how far off axis the listeners are. The degree of angle correction is calculated by a processor in the sound projector in accordance with the known beam dimensions at various angles.

The arrangements of Figures 2 and 3 allow two people sitting in the same room to selectively listen to an audio programme. That is, a first listener may listen to an audio programme emitted by the Sound Projector, while the second listener hears nothing or very little (perhaps other than low amplitude sound reflected from walls and other features). Or similarly, the second listener could listen, while the first did not. Thus the invention can provide a selective mute function for two persons in the same room.

The direction in which the muting beam (the inverse beam 871) needs to be sent in order to effect sound cancellation at the listener position 85 is a function of the geometry and can be calculated or simulated by known techniques. For an arrangement where the listening positions are known and fixed (for example in a listening room with fixed seating), this information can be programmed into the Sound Projector and brought into play when one or other listener selects the mute

function, for example via a hand-held remote control. In general, however, listening positions are neither known nor fixed a priori. The known Sound Projector allows user control of the sound beam directions, again preferably via a hand-held remote control, and this technology can be readily extended to directing the muting beam. Thus on selecting mute, the user is given the option to steer the muting beam to fine-tune its direction (and/or its phase and amplitude) until optimum sound cancellation is achieved.

In a further variant, the direction of the muting beam as a function of listening positions may be pre-programmed into the Sound Projector and the actual listening positions detected by some means in real time. Position detection may be according to the means taught in co-owned international application WO01/23104, for example using the time of arrival of test signals from the Sound Projector at a microphone located in a user-held remote control to triangulate the microphone's position, or by other means such as Infra Red sensing.

Figure 4 shows a further variant of the invention in which the two listeners 84, 85 listen to two different audio programmes simultaneously. The arrangement of Figure 3 is essentially repeated for the second listener, such that each listener receives a sound beam according to their selected audio programme and the other's beam is muted at their location by means of an additional cancelling sound beam. Thus, as above, first listener 84 receives sound beam 87 and an inverse beam is directed to the far side of listener 85 to produce nulling in the direction of the second listener 85. At the same time, a second beam 88 carrying a different audio programme is directed to second listener 85 and an inverse beam 881 (that is, an inverse of beam 88) is directed to the far side of the first listener 84 to produce nulling in the direction of the first listener 84. Figure 4B shows this effect graphically, as before showing SPL as a function of position. The solid line represents the SPL sum of amplitudes of beam 87 and its inverse 871, while the dashed line represents the SPL resulting from the sum of amplitudes of beam 88 and its inverse 881. Thus the sound level of the first audio programme (solid lines) is high at position 84 and very low at position 85, while the sound level of the second audio programme (dashed lines) is high at position 85 and very low at position 84.

The arrangement of Figure 4 therefore allows two listeners in the same room to each listen to different audio programmes without undue interference from the other listener's programme. It is as though the sound has been split for the two listeners. Optimisation of the nulling for each listener may be carried out independently by similar means to those described for selective muting above.

It has already been explained that the interference to one listener is more pronounced at low frequencies. A preferable aspect of the invention therefore includes limiting the frequency range of the cancelling beam 871 or 881 so as to only include low frequency components. The cancellation of any high frequency components can be unnecessary because the sound beams at high frequencies are already very narrow. Further, including the high frequency components in a cancelling beam may cause additional problems as the high frequency cancelling components may get reflected back to the listeners unintentionally. The exact frequency cut-off used is dependent to some extent on the position of the listeners. As a general rule, the cancelling beam (the second and fourth beams mentioned in the claims) 871,881 can comprise only those frequency components below 2 kHz. For listeners sitting at +10 degrees and – 10 degrees (i.e.20 degrees apart), the cut-off frequency can be calculated as 1.2 kHz. In this case the cancelling beams 871,881 can be made to contain only those signals below 1.2 kHz.

For clarity, Figures 2 to 4 show the Sound Projector 80 parallel to the line A-A' joining the listeners. This need not be so. The Sound Projector may be angled to the listeners; that is, the listeners may be at different distances from the Sound Projector. Similarly, the listeners need not be disposed symmetrically about the Sound Projector. These variants are included in the invention. In these cases, fine-tuning of phase and amplitude of the cancelling beam can improve the cancellation effect.

Figures 5-7 show simulated performance of the 'split sound' arrangement of Figure 4 at illustrative frequencies. The figures show SPL (vertical axis) against angular position (horizontal axis; note that this differs from the axis on Figures 2-4, which has a distance scale). In each case, the upper figure shows the first and second sound beams 87,88 and their complementary cancelling beams 871, 881 and the lower figure shows the sums of the beam pairs. The listener positions 84,85 are +10 degrees and -

10 degrees off axis. Figure 5 shows both main beams at 400 Hz, Figure 6 shows both main beams at 1000 Hz and Figure 7 shows the first beam at 1000Hz and the second at 400 Hz.

The particular Sound Projector design used to generate the simulations of Figures 5-7 comprises a line array of 20 transducers spaced 40 mm apart, with total length about 800 mm. Many other Sound Projector designs could be used.

The effect of frequency on beam width can be seen by comparing the main beam 87 in the upper traces of Figures 5 and 6. In Figure 5, 400 Hz, the main beam 87 is directed at first listener 84 at -10 deg, at which position the beam is full power, i.e. SPL is 0 dB. SPL falls off to either side but the beam is broad e.g. the -3 dB cut-off is at about -37 deg and +17 deg, corresponding to a (-3dB) beam width of 54 deg. Thus at the position of second listener 85, +10 deg, the SPL is about -1.5 dB, close to full power. In comparison, at 1000 Hz, Figure 6, the -3 dB beam width is considerably less (about 22 deg) and the SPL at second listener position 85 is much lower, at about -17 dB. However, Figure 6 also illustrates the occurrence of sidelobes to either side of the main beam. For example, the first side lobe 872 of beam 87 peaks at about +23 deg. As the frequency increases, the main beam 87 narrows but the sidelobes become more closely spaced.. Thus, without cancellation, sidelobes may also contribute to sound at the second listener position 85.

As before, an inverse sound beam 871 is directed to the far side of second listener 85, in this case to about +30 deg. The angle between the listeners 84,85 is 20 deg (-10 deg to +10 deg) as is the angle between second listener 85 and the inverse beam (+10 deg to +30 deg). As can be seen in the upper plots of Figures 5 and 6, the inverse beams 871 show similar features to the main beam in terms of beam width and sidelobes.

The lower plots of Figures 5 and 6 show the sum of beams 87 and 871 at line 50. In both cases, there is a deep null (more than -30 dB) at second listener position 85 while the signal at first listener position is close to full power (within +/- 4 dB). Note that the null is formed at the same place independent of frequency, beam width or sidelobes.

A second beam 88 directed at second listener 85 is also shown in the upper plots of Figures 5 and 6, together with its inverse 881, directed appropriately (-30 deg). The resultant is shown in the lower plots at line 60, again showing close to full power sound at second position 85 and a null of more than -30 dB at first position 84.

Figure 7 similarly shows strong main beams and deep nulls at the listener positions for a case where the beams are at different frequencies (1000 Hz and 400 Hz respectively). By extension, it is clear that the invention is applicable across a broad range of frequencies, and hence for broadband signals.

The sound projector 80 of the present invention preferably has a processor which determines the amplitude and timing of signals sent to each sonic output transducer. Appropriate beams can be formed by adjusting the amplitude and timing of the signals, in accordance with the teaching found in WO01/23104 and WO02/078388. Once the processor is provided with the listening positions, it can calculate the beam angles for all of the beams. Such calculation can be performed in real time or can be carried out by way of a look-up table. For example, the processor could consult a table giving the angle of the beams and any amplitude or angle adjustments that are required for any pair of listening positions. It is not actually necessary that beam angles are directly calculated and instead a series of delay values for each transducer can be calculated or determined for particular listening positions.

The means for adjusting the signals and sound beams can be implemented in hardware or software. For example, the amplitude adjuster and inverter that is used to create the second sound beam can be provided by suitably programmed software filters as can the low pass filter if the embodiment in which only low frequencies are cancelled is implemented.

The one or two audio programmes described in the above may be provided by an audio device such as a CD player or by an audio-visual device (such as a television, a video or DVD player or a computer) or by any other multi-media device. It may be that one listener receives sound from one device, say a CD player, while the other receives sound from another device, for example a television. In this case, the

respective players are connected to, and send signals to, the Sound Projector, which outputs the respective sound beams. In a further variant of the invention, the Sound Projector is incorporated within an audio or audio-visual device, for example a television.

All of the patent documents and references referred to above are hereby incorporated by reference.

Although what has been described above is the production of one or two simultaneous sound presentations and null points, the invention extends to 3 or more such.

CLAIMS

1. A method of creating a sound field comprising a strong first sound signal at a first location and a weak or null first sound signal at a second location, said method comprising:

directing a first sound beam towards the first location to create said strong first sound signal there;

directing a second sound beam towards a third location different to said second location, such that the first and second sound beams cancel at said second location to create said weak or null first sound signal there.

2. A method according to claim 1, wherein said second location lies between said first and third locations.

3. A method according to claim 1 or 2, wherein said sound field is created by a sound emitter having a centroid of sound generation.

4. A method according to claim 3, wherein said first location lies in a first direction from said centroid, said second location lies in a second direction from said centroid and said third location lies in a third direction from said centroid, and wherein said second direction bisects the angle between said first and third directions.

5. A method according to any one of the preceding claims, wherein said second sound beam is amplitude adjusted to account for the fact that said second sound beam is wider than said first sound beam.

6. A method according to any one of the preceding claims, wherein said second direction is adjusted to account for the fact that said second sound beam is wider than said first sound beam.

7. A method according to any one of the preceding claims, wherein said second sound beam is an inverse of said first sound beam.

8. A method according to any one of the preceding claims, wherein said sound field further comprises a strong second sound signal at said second location and a

weak or null second sound signal at said first location, such that a listener at said first location hears substantially only said first sound signal and a listener at said second location hears substantially only said second sound signal, said method additionally and simultaneously comprising:

directing a third sound beam towards the second location to create said strong second sound signal there;

directing a fourth sound beam towards a fourth location different to said first location, such that the third and fourth sound beams cancel at said first location to create weak or null second sound signal there.

9. A method according to claim 8, wherein said first location lies between said fourth and second locations.

10. A method according to claim 8 or 9, wherein said fourth location lies in a fourth direction from the or a centroid of sound generation, and wherein said first direction bisects the angle between said fourth and second directions.

11. A method according to any one of claims 8 to 10, wherein said fourth sound beam is amplitude adjusted to account for the fact that said fourth sound beam is wider than said third sound beam.

12. A method according to any one of claims 8 to 10, wherein said fourth direction is adjusted to account for the fact that said fourth sound beam is wider than said third sound beam.

13. A method according to any one of claims 8 to 12, wherein said fourth sound beam is an inverse of said third sound beam.

14. A method according to any one of claims 8 to 13, wherein said fourth sound beam only comprises low frequency components under 2 kHz.

15. A method according to any one of the preceding claims wherein said second sound beam only comprises low frequency components under 2 kHz.

16. A method according to any one of the preceding claims, wherein said sound field is created by a sound projector comprising a plurality of sonic output transducers, said transducers outputting suitably delayed replicas of said first sound signal in order to direct said first and second sound beams towards said first and third locations respectively.

17. A method according to claim 16, wherein said output transducers are arranged in a horizontally disposed array.

18. A method according to claim 16, wherein said output transducers are arranged in a two-dimensional array lying in a vertical plane.

19. A method according to any one of the preceding claims, further comprising allowing a user to control the position of said first location or said second location.

20. A method according to any one of the preceding claims, further comprising calculating the angle of said second sound beam based on said second location.

21. Apparatus for creating a sound field that comprises a strong first sound signal at a first location and a weak or null first sound signal at a second location, said apparatus comprising:

a plurality of sonic output transducers capable of directing more than one sound beam, each beam being different,

wherein, in use, a first sound beam is directed towards said first location to create said strong first sound signal there;

a processor arranged to calculate the angle of a second sound beam based on said second location, such that said second sound beam is not directed towards said second location but instead towards a third location;

wherein, in use, said second sound beam is directed towards said third location such that the first and second sound beams cancel at said second location to create said weak or null first sound signal there.

22. Apparatus according to claim 21, further comprising an amplitude adjuster for adjusting the amplitude of said second sound beam to account for the fact that said second sound beam is wider than said first sound beam.

23. Apparatus according to claim 21 or 22, wherein said processor is arranged to correct the calculated angle of said second sound beam to account for the fact that said second sound beam is wider than said first sound beam.

24. Apparatus according to any one of claims 21 to 23, further comprising an inverter arranged to invert said first sound signal so as to provide the signal for said second sound beam.

25. Apparatus according to any one of claims 21 to 24, further comprising a low pass filter for filtering out frequency components of said second sound beam above 2 kHz.

26. Apparatus according to any of one of claims 21 to 25, wherein said apparatus is a sound projector in which said plurality of sonic output transducers output suitably delayed replicas of said first sound signal in order to direct said first and second sound beams towards said first and third locations respectively.

27. Apparatus according to claim 26, wherein said plurality of sonic output transducers are disposed in a line array.

28. Apparatus according to claim 26, wherein said plurality of sonic output transducers are disposed in a two-dimensional array.

29. Apparatus according to any one of claims 21 to 28, further comprising a remote control arranged to provide signals to said processor regarding desired listening position, said processor using said signals when calculating the angles of said first and second sound beams.

30. A method of creating a sound field comprising a strong sound signal in a first location and a weak or null sound signal in a second location by directing a first sound

beam towards the first location and directing a second sound beam in a different direction such that the first and second sound beams effectively cancel at the second location.

31. A method of creating a sound field comprising a strong signal in a first direction from a sound emitter and a weak or null signal in a second direction from said sound emitter, by

directing a first sound beam from said emitter in said first direction;

directing a second sound beam from said emitter in a third direction;

wherein said second direction lies between said first and third directions, and said second sound beam is essentially an inverse of said first sound beam.

Fig. 1.
(Prior art)

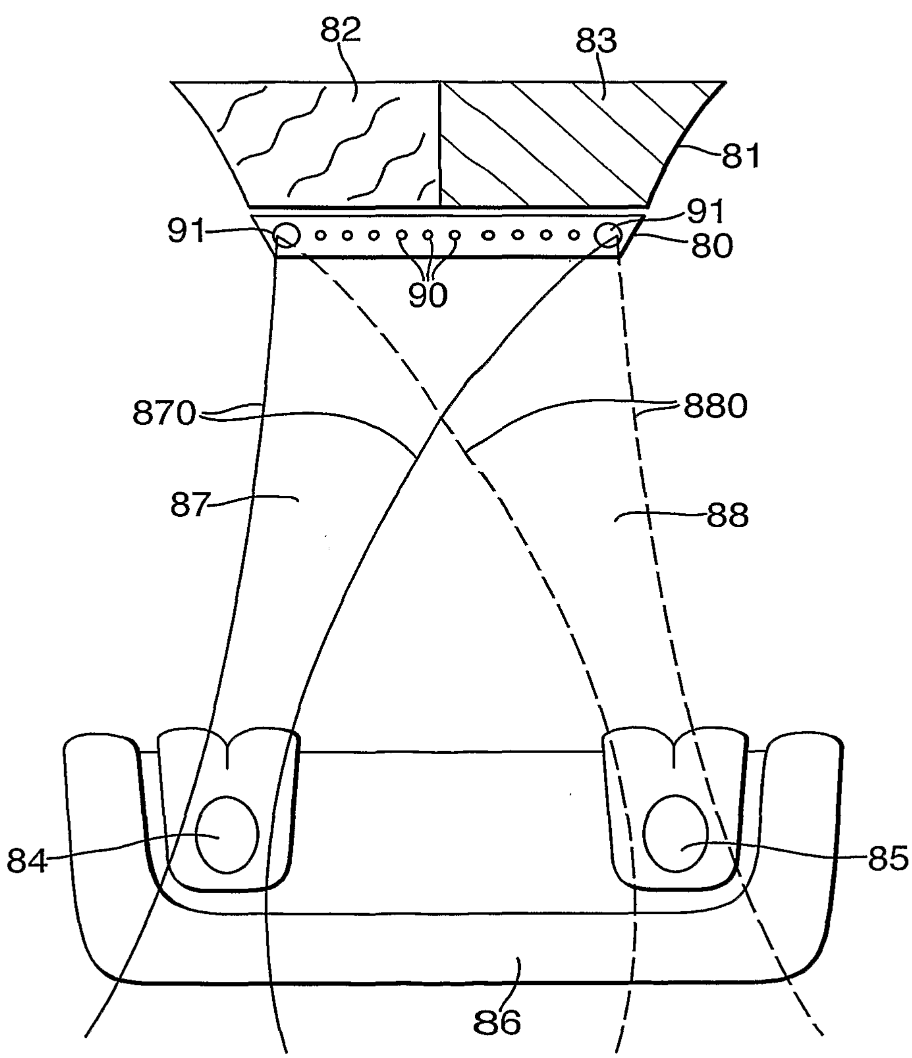


Fig.2A.

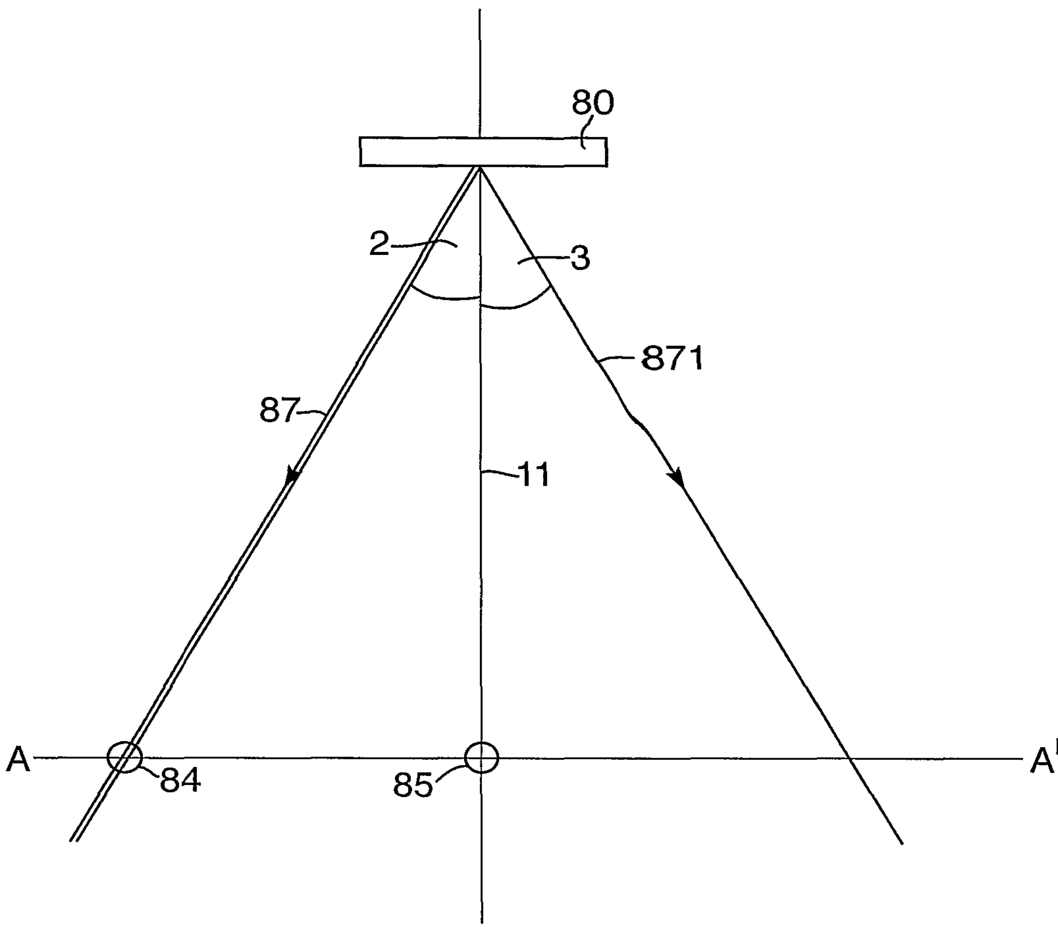


Fig.2B.

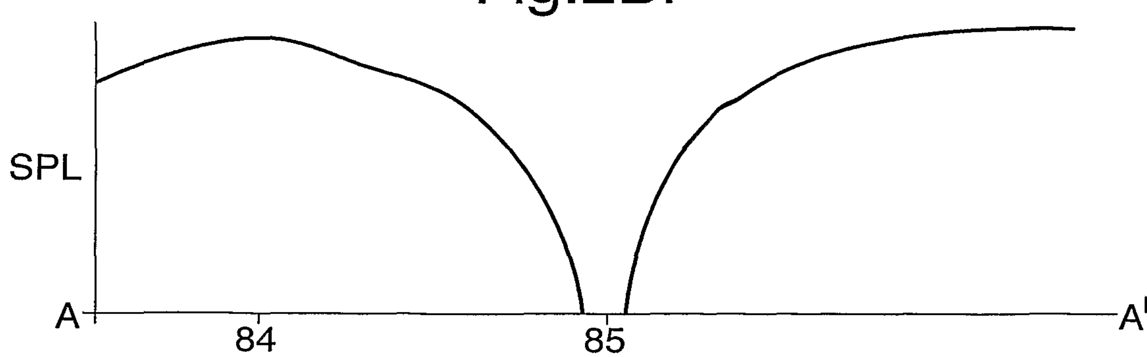


Fig.3A.

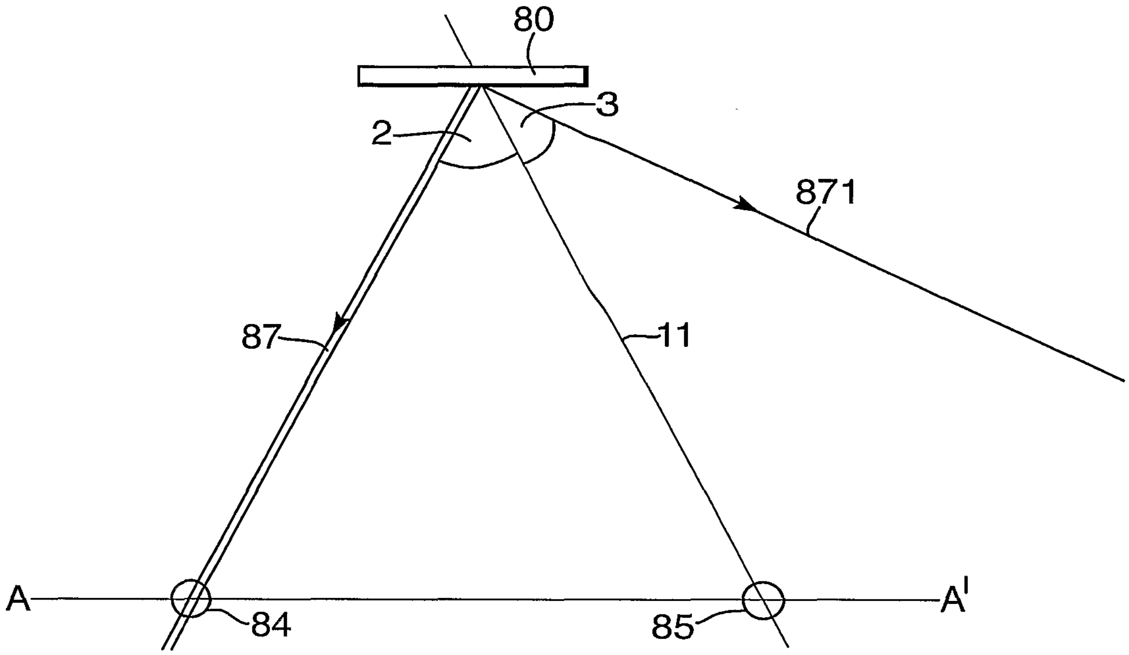


Fig.3B.

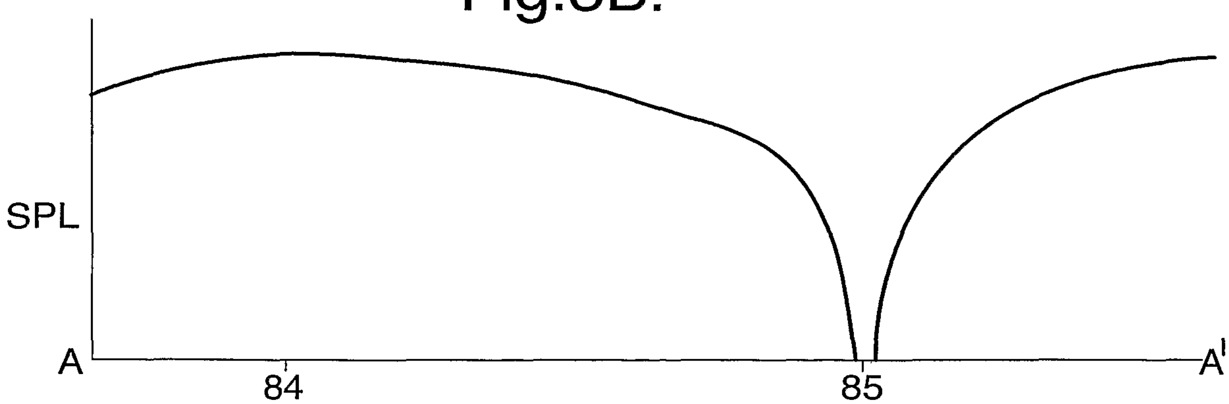


Fig.4A.

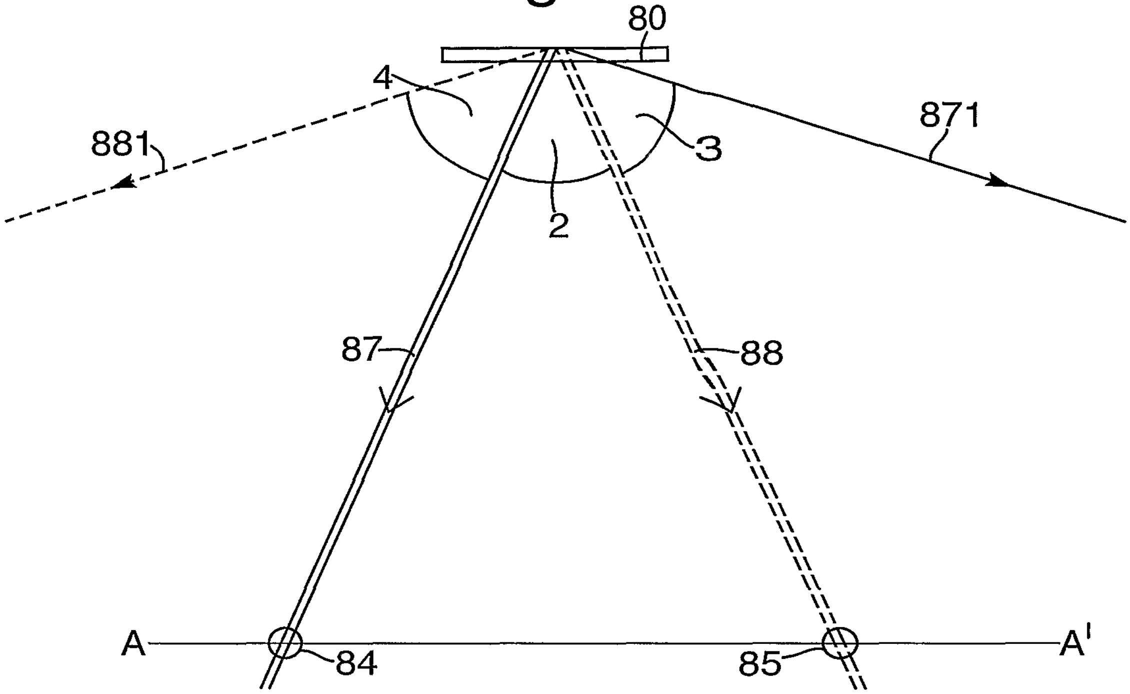


Fig.4B.

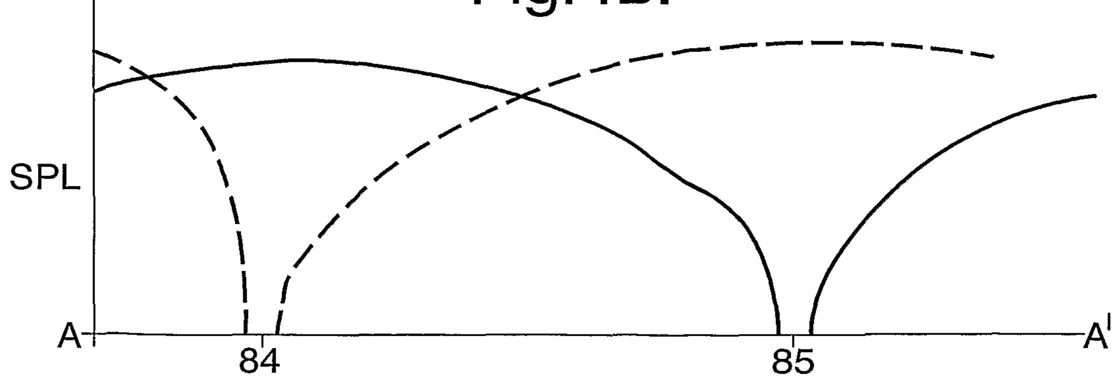
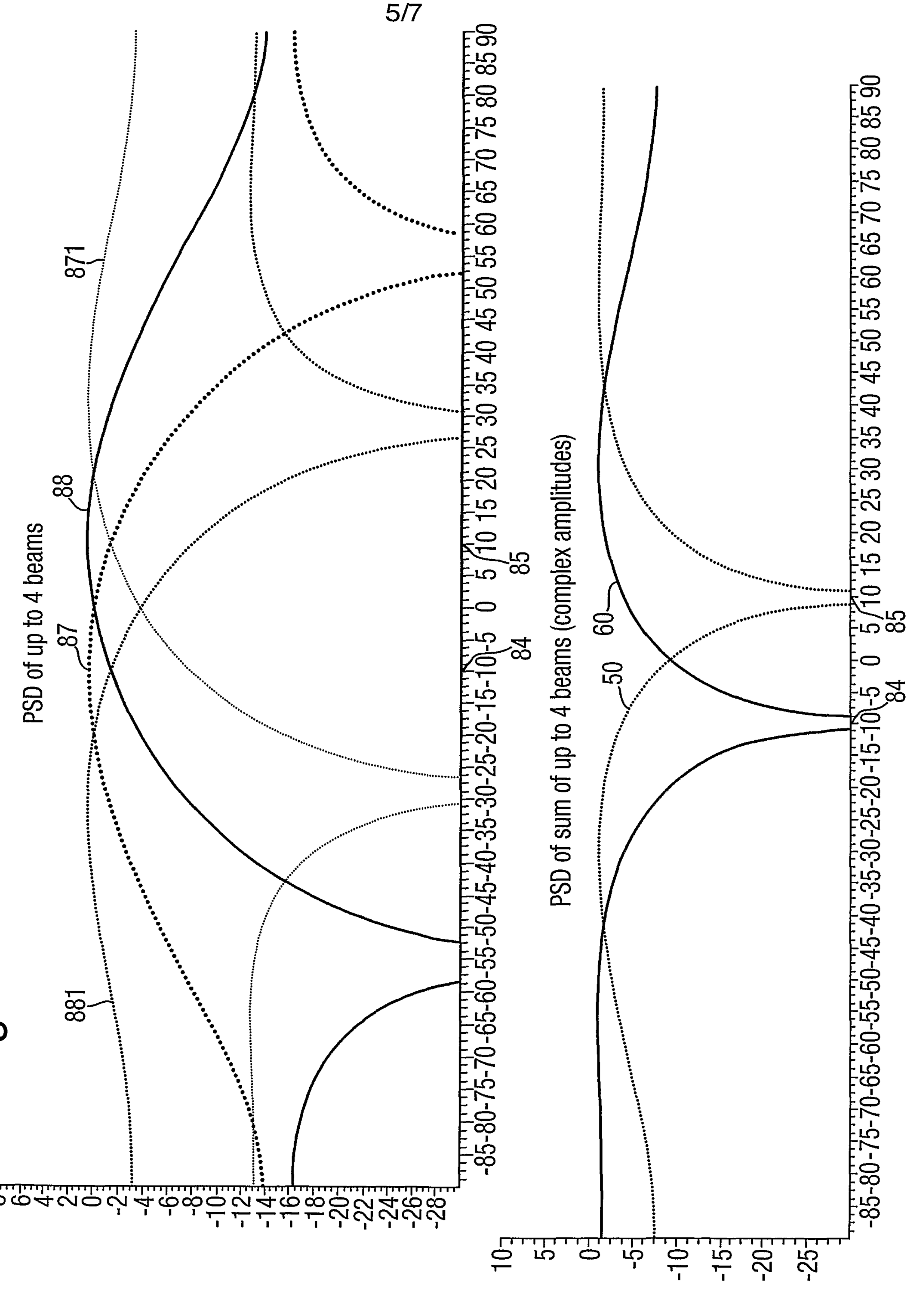


Fig.5.


PSD of up to 4 beams
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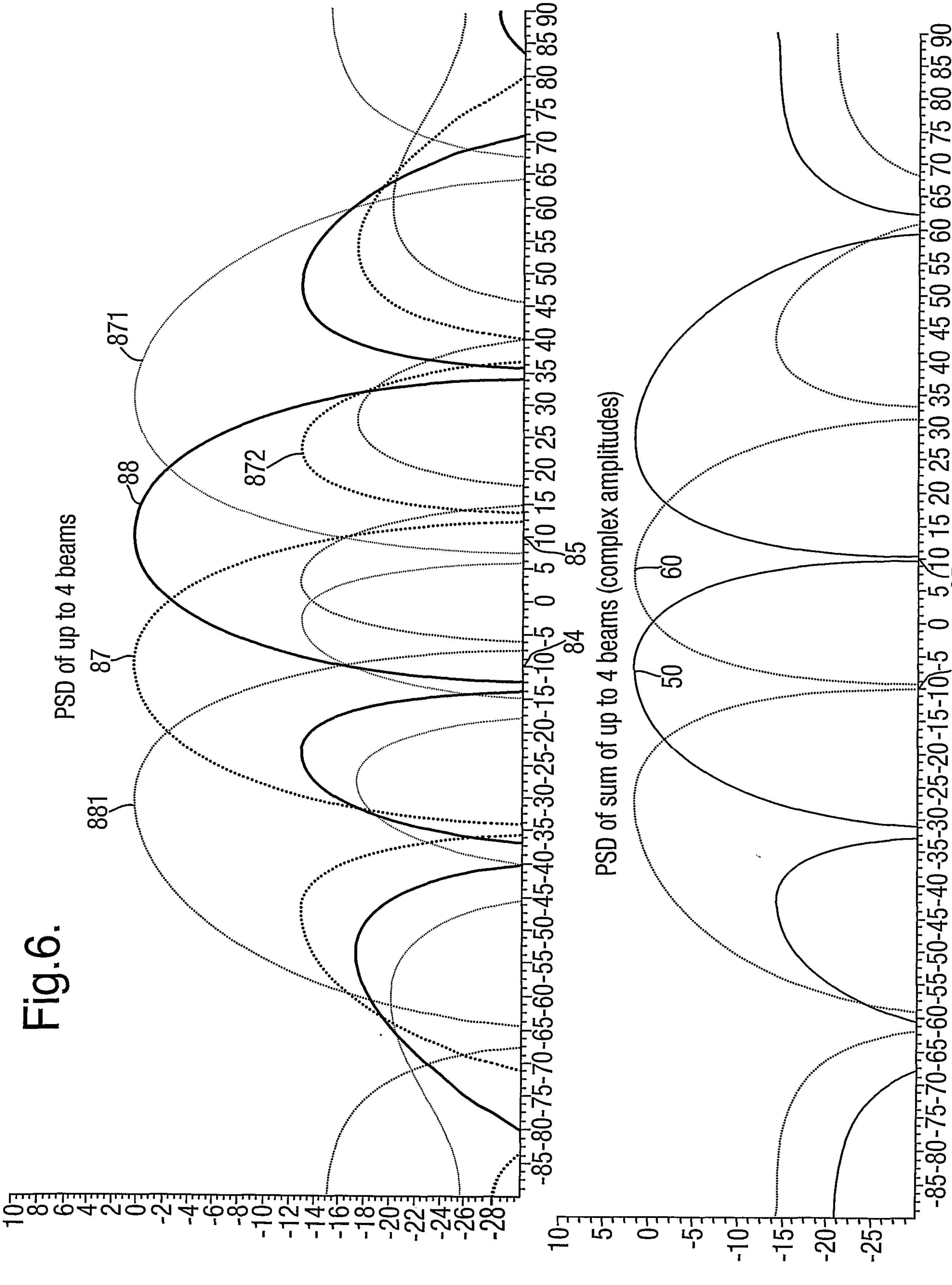
871
88
87
84
85
PSD of sum of up to 4 beams (complex amplitudes)
60
50
84
85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PSD of sum of up to 4 beams (complex amplitudes)
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60
84
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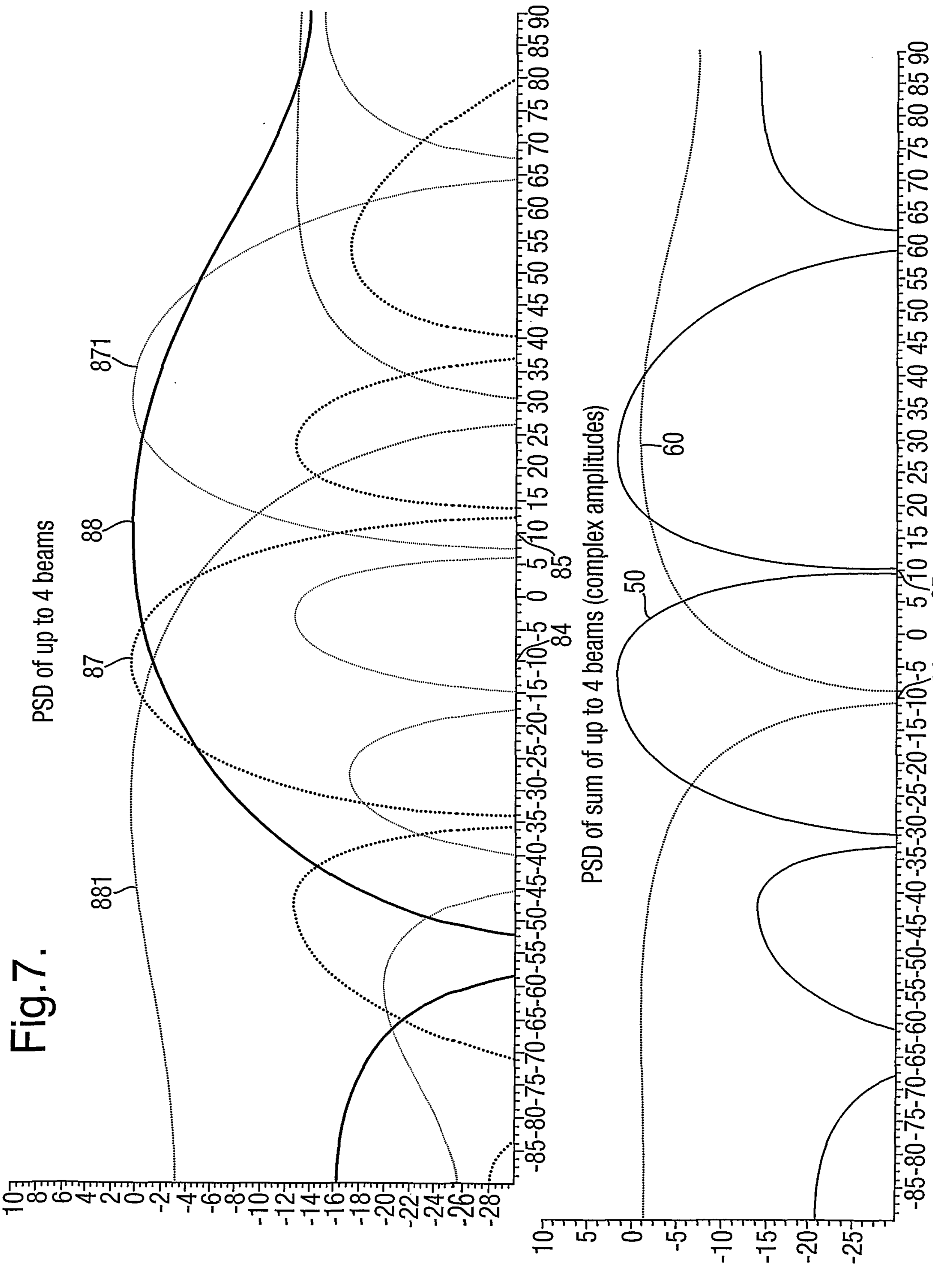
Fig.6.

Fig.7.


PSD of up to 4 beams
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85
PSD of sum of up to 4 beams (complex amplitudes)
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2005/000887

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04R3/12 H04R1/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04R G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 3 992 586 A (JAFFE ET AL) 16 November 1976 (1976-11-16) figures 1-3 column 1, line 60 - column 2, line 5 column 2, line 67 - column 3, line 4 column 3, line 50 - line 57 claim 1 -----	1-15,30, 31 16-29
A Y	WO 03/071827 A (1... LIMITED; TROUGHTON, PAUL, THOMAS; BIENEK, IRVING, ALEXANDER; SHEP) 28 August 2003 (2003-08-28) figures 1A,1B,2 page 5, line 3 - line 11 page 6, line 9 - line 18 -----	1-15,30, 31 16-29

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 2005	24/06/2005

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern: l Application No
PCT/GB2005/000887

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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WO 03071827	A	28-08-2003	AU	2003207322 A1	09-09-2003
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